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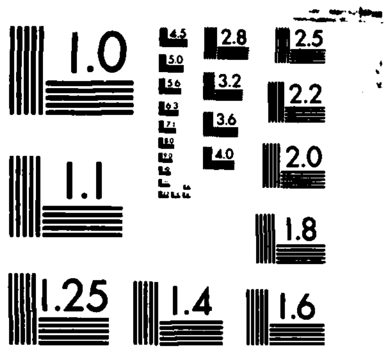

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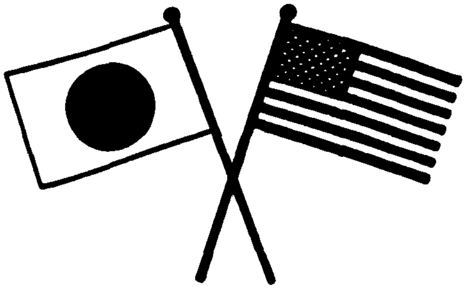

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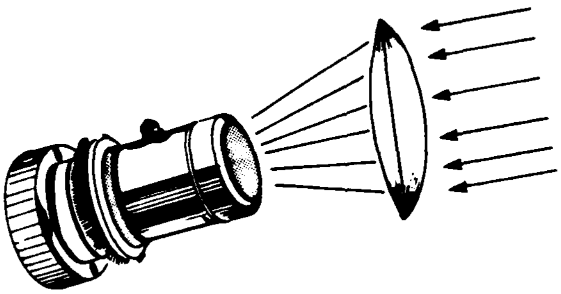

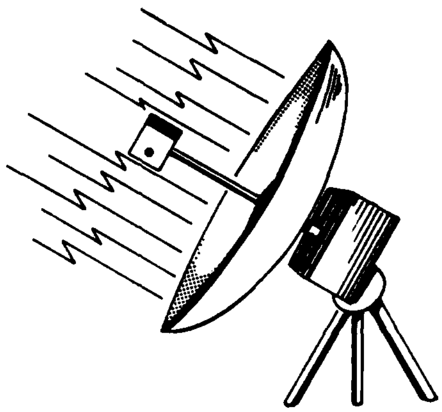

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20. ABSTRACT (*Continue on reverse side if necessary and identify by block number*)

This document is a report on the first DoD technology team review of Japanese programs in electro-optical (EO) millimeter and microwave technology of interest to the Department of Defense. The team visited Japan during July 1984 and April 1985 and reviewed EO/MMW activities at a number of companies and government research centers.

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ELECTRO-OPTICS MILLIMETER/MICROWAVE TECHNOLOGY IN JAPAN

Report of DoD Technology Team

May 1985

EXECUTIVE SUMMARY

In January 1983, the Japanese government, headed by Prime Minister Nakasone, decided to extend Japan's defense cooperation by offering the release of military technologies to the U.S. A framework for the transfer of military technologies from Japan was established in November 1983 when the U.S. and Japan exchanged notes on the transfer of military technology. The notes provided an overall framework for the transfer of Japanese military technologies with potential benefit to U.S. defense capabilities.

As part of ongoing efforts to support this agreement, the Office of the Under Secretary of Defense for Research and Engineering (OUSDRE) proposed the creation of teams of DoD scientists and engineers to identify U.S. requirements, research Japanese technology programs, and visit key Japanese facilities and counterparts to identify technological areas for potential cooperation programs of mutual U.S. and Japan benefit.

The first Technology Team was created to review Japanese programs in electro-optics (EO) and millimeter-wave (MMW) technologies; investigate technological areas of interest; study mechanisms of technology transfer and modes of cooperation; and recommend structures for future reviews and further data exchanges. The eleven Technology Team members were selected for their expertise. (Brief biographies are provided in Appendix A.)

Dr. John MacCallum
  Team Leader, DoD/OUSDRE
Mr. George Nicholas, DoD/OUSDRE
Dr. Sam Musa, DoD Consultant
Dr. Thomas Hartwick, DoD Consultant
Dr. Barry Spielman, NRL
Dr. Patrick McDermott, DoD Consultant
Mr. Charles Freeman, NVEOL
Dr. John Kuno, DoD Consultant
Dr. Anthony DeMaria, DoD Consultant
Dr. Ken Ando, DARPA
Dr. Ronald Paulson, AF Wright
  Aeronautical Labs

The Team met five times to outline project objectives, to be briefed by experts on Japan, to discuss previously published work on Japanese electro-optic and millimeter-wave technologies, and finally to select sites for visits and draft questions for Japanese counterparts. The Team's efforts were culminated by a trip to Japan from the 9th to the 20th of July 1984 to visit facilities and counterparts previously identified. This report is based on the findings and recommendations which came out of those meetings and the trip.

The Team was successful in initiating dialogue on technology exchange. A number of electro-optic and millimeter-wave technology activities of interest have been identified in Figure E-1. These activities include not only items for purchase but also manufacturing methods and know-how, design and test data.

The Team found that, generally, while Japan lags in defense system development, Japanese management techniques are very effective at transitioning technology from research and development (R&D) to production phases. Figure E-2 shows a number of areas where the Technology Team observed EO/MMW technologies of interest. The marks (Xs) in Figure E-2 represent technologies observed or described in literature provided during the company visits.

TECHNOLOGIES OF INTEREST

DESIGN/TEST DATA

- T/R MODULES
- LOCAL AREA NETWORKS (LAN)
- * OPTICAL DATA STORAGE
- SEMICONDUCTOR LASERS
- * DFB LASERS AT 1.3 micron
- FIBER OPTIC GYROS
- ACTIVE APERTURE SYSTEMS
- HIGH ELECTRON MOBILITY TRANSISTORS
- * HgCdTe
- SCHOTTKY BARRIER IR DEVICES
- VOICE RECOGNITION & SYNTHESIS
- LITHIUM BATTERIES
- * LASER DIODES
- LAN COMPONENTS

PRODUCTION METHODS & KNOW-HOW

- BROAD-BAND PHASED ARRAYS
- SEEKERS
- * FIBER OPTIC LANs
- FIELD EFFECT TRANSISTORS
- * GaAs WAFERS
- IR FO WAVEGUIDES
- * LIQUID CRYSTAL DISPLAYS
- * ELECTRIC LUMINESCENT DISPLAYS
- LOW COST GYROS
- * III-V MATERIALS
- BARIUM-ZINC-TANTALUM COMPOUND MATERIALS
- AUTOMATED MANUFACTURE OF EO MATERIALS & DEVICES
- ERASABLE OPTICAL DATA STORAGE
- MATERIALS FOR CO_2 LASERS

POTENTIAL SUPPLY SOURCE

- * SOLID STATE IMAGER CHIPS
- PIN/FET
- * LASER DIODES
- APD DETECTORS
- E-O MATERIALS
- * HIGH DENSITY MEMORIES
- MICROWAVE & MMW COMPONENTS
- GaAs WAFERS

* Technologies of High Interest.

FIGURE E-1

Sites Visited by the Technology Team	GaAs Materials	Devices and Components	Systems	Active Apertures	DBS Receivers	Lasers	Optical Processing	Optical Data Storage	Visible Imager	Infrared Imager	Visible Night Vision Devices	LAN Components	Fiber Optic Gyros	Displays
	MM-WAVE/μ-WAVE TECHNOLOGIES					E-O TECHNOLOGIES								
TRDI #1						X			X	X	X			
TRDI #3		X	X	X						X			X	
NIPPON ELECTRIC COMPANY		X	X		X	X	X		X	X			X	
HITACHI					X	X		X	X	X		X		
FUJITSU	X	X	X		X			X		X		X		X
MITSUBISHI ELECTRIC COMPANY		X	X	X	X	X			X	X	X	X		X
TOSHIBA		X	X		X	X	X	X	X	X		X		
SHARP		X			X	X		X						
SUMITOMO	X	X				X						X	X	
MATSUSHITA		X	X		X	X	X	X	X			X		

FIGURE E-2

ORGANIZATION/TECHNOLOGY MATRIX

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APPENDIX A - BIOGRAPHIES

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1.0 U.S. AND JAPANESE COOPERATION ON TECHNOLOGY TRANSFER

1.1 INTRODUCTION

It is apparent to many within the U.S. Government -- and particularly the Department of Defense (DoD) -- that national security is increasingly dependent on state-of-the-art research and advanced technology. The U.S. is no longer the only source, or even the leader, in all advanced technologies. It has become increasingly advantageous to capitalize on advanced technologies developed by U.S. allies in addition to developing domestic sources. For this and other political reasons, the U.S. Government has become involved with international cooperation agreements in research and development (R&D) of technologies with military applications.

In 1980, a joint Systems and Technology Forum (S&TF) was established between the Office of the Under Secretary of Defense for Research and Engineering (OUSDRE) and the Japan Defense Agency (JDA) Equipment Bureau to facilitate cooperation between JDA and DoD in the research, development, production, and procurement of military equipment.

In January 1983, the Japanese government, headed by Prime Minister Nakasone, reached the conclusion that it would open a way for the transfer to the U.S. of military technology. This decision, which was a significant event in expanding technology cooperation, was made public in the form of the Statement of the Chief Cabinet Secretary. It stated that, in response to U.S. requests, Japan would be allowed to export military technology to the United States, and only to the United States. This statement was followed by an exchange of notes between the two governments in order to implement this decision (see Appendix B). The rationale for this decision was to reciprocate in the exchange of defense-related technologies in order to ensure the effective operation of the Japan-U.S. security arrangements. There has been a long history of technology transfer from the U.S. to Japan in licensing agreements for the production of defense-related equipment.

As a result of this agreement, DoD, under the leadership of Dr. Edith Martin, then Deputy Under Secretary of Defense for Research and Advanced Technology (DUSD/R&AT), arranged for visits of teams of U.S. scientists representing DoD to Japanese research centers (see Figure 1). This concept involved having DoD scientists and engineers, who are experts in various key disciplines, identify U.S. requirements, research Japanese technological programs and finally to visit key Japanese counterparts in the selected disciplines to explore the potential for cooperative programs of mutual interest.

1.2 BACKGROUND

The first Technology Team, as proposed by the OUSDRE, was chartered to review Japanese programs in electro-optics (EO) and millimeter-wave (MMW) technologies. The Team met five times to outline project objectives, to be briefed by experts on Japan, and to discuss previously published work on Japanese electro-optic and millimeter-wave technology, and finally to select sites for visits and draft questions for Japanese counterparts. The Team's efforts culminated in a trip to Japan from the 9th to the 20th of July 1984 to visit facilities and counterparts previously identified. This report is based on the findings which came out of those meetings and the trip.

ITINERARY FOR FIRST TECHNOLOGY TEAM

DATE	VISIT
9 July (Mon)	Japan Defense Agency (JDA)
10 July (Tues)	Ministry of International Trade and Industry (MITI)
11 July (Wed)	Nippon Electric Company (NEC) Hitachi
12 July (Thurs)	Fujitsu Mitsubishi Electric Company (MELCO)
13 July (Fri)	Toshiba
14-15 July (Sat-Sun)	
16 July (Mon)	Sharp
17 July (Tues)	Sumitomo
18 July (Wed)	Matsushita
19 July (Thurs)	JDA
20 July (Fri)	MITI

FIGURE 1

1.3 KEY JAPANESE GOVERNMENT ORGANIZATIONS

Japanese government organizations that play major roles in defense include the Japan Defense Agency, Ministry of International Trade and Industry (MITI), and the Ministry of Foreign Affairs (MOFA). (See Figure 2.) These organizations develop and ratify policy; coordinate government-industry activities; make procurement decisions; issue export licenses; and handle inter-governmental relations.

1.3.1 Japan Defense Agency (JDA)

Within the Japanese government, the JDA has a primary role for defense-related R&D as well as for acquisition of equipment, with the Equipment Bureau having responsibility for supervision of these programs. The JDA formulates equipment requests and contracts with Japanese industry to produce the equipment. For certain systems and components, JDA may make purchases from foreign sources. In addition to its primary role for the acquisition of equipment, JDA is in charge of formulating defense-related R&D policy, and actual R&D activities are carried out by the Technical Research and Development Institute (TRDI), a subordinate organization to the JDA, under the supervision of the Equipment Bureau.

The basic R&D policy of the JDA is to formulate a future R&D vision based on requirements from the Self Defense Forces and to conduct actual defense-related R&D activities making use of R&D results of the commercial sector. There is no arsenal of weapons within the government and production of weapons is left to Japanese industries. Figure 3 shows the research centers of Japan's primary defense research organization. The Technology Team visited the First and Third Research Centers of the TRDI.

1.3.2 Ministry of International Trade and Industry (MITI)

MITI's role within the Government of Japan (GoJ) is to coordinate policy regarding the future structure of Japanese industry and to promote the optimization of industrial activities. In addition to its coordinating role for such industrial policies, MITI also has a primary role in the formulation of export policy, authorizing transfer abroad of certain technologies in accordance with the relevant laws and regulations. Japan has tightly restricted its arms export and military technology transfer under the Three Principles on Arms Export (1967) and the Government Policy Guideline on Arms Export (1976). In 1983 a special exception was made to allow the United States access to military technology. Similar transfers to other countries have been tightly restricted, as mentioned above.

Initiatives exist in Japanese industries for deciding how and what technologies are to be transferred. MITI's position is that its role is to support the decisions of Japanese industry, not make decisions for them. Technology is the "treasure" of the company -- not the government. Therefore, the company has a major role in deciding on the release of information.

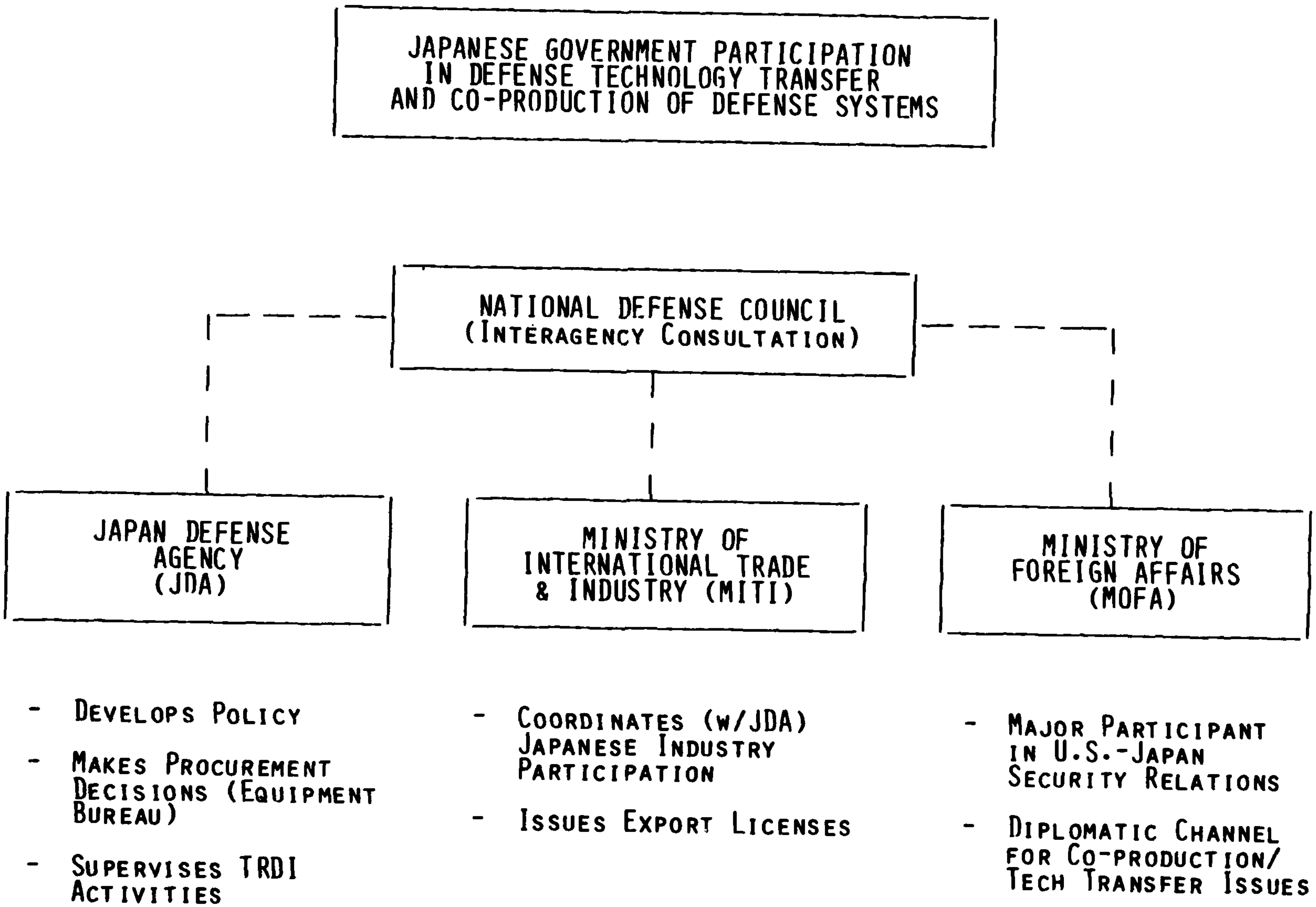
JAPANESE GOVERNMENT PARTICIPATION IN DEFENSE TECHNOLOGY TRANSFER AND CO-PRODUCTION OF DEFENSE SYSTEMS
NATIONAL DEFENSE COUNCIL (INTERAGENCY CONSULTATION)
JAPAN DEFENSE AGENCY (JDA)
MINISTRY OF INTERNATIONAL TRADE & INDUSTRY (MITI)
MINISTRY OF FOREIGN AFFAIRS (MOFA)
- DEVELOPS POLICY
- MAKES PROCUREMENT DECISIONS (EQUIPMENT BUREAU)
- SUPERVISES TRDI ACTIVITIES
- COORDINATES (W/JDA) JAPANESE INDUSTRY PARTICIPATION
- ISSUES EXPORT LICENSES
- MAJOR PARTICIPANT IN U.S.-JAPAN SECURITY RELATIONS
- DIPLOMATIC CHANNEL FOR CO-PRODUCTION/TECH TRANSFER ISSUES

FIGURE 2

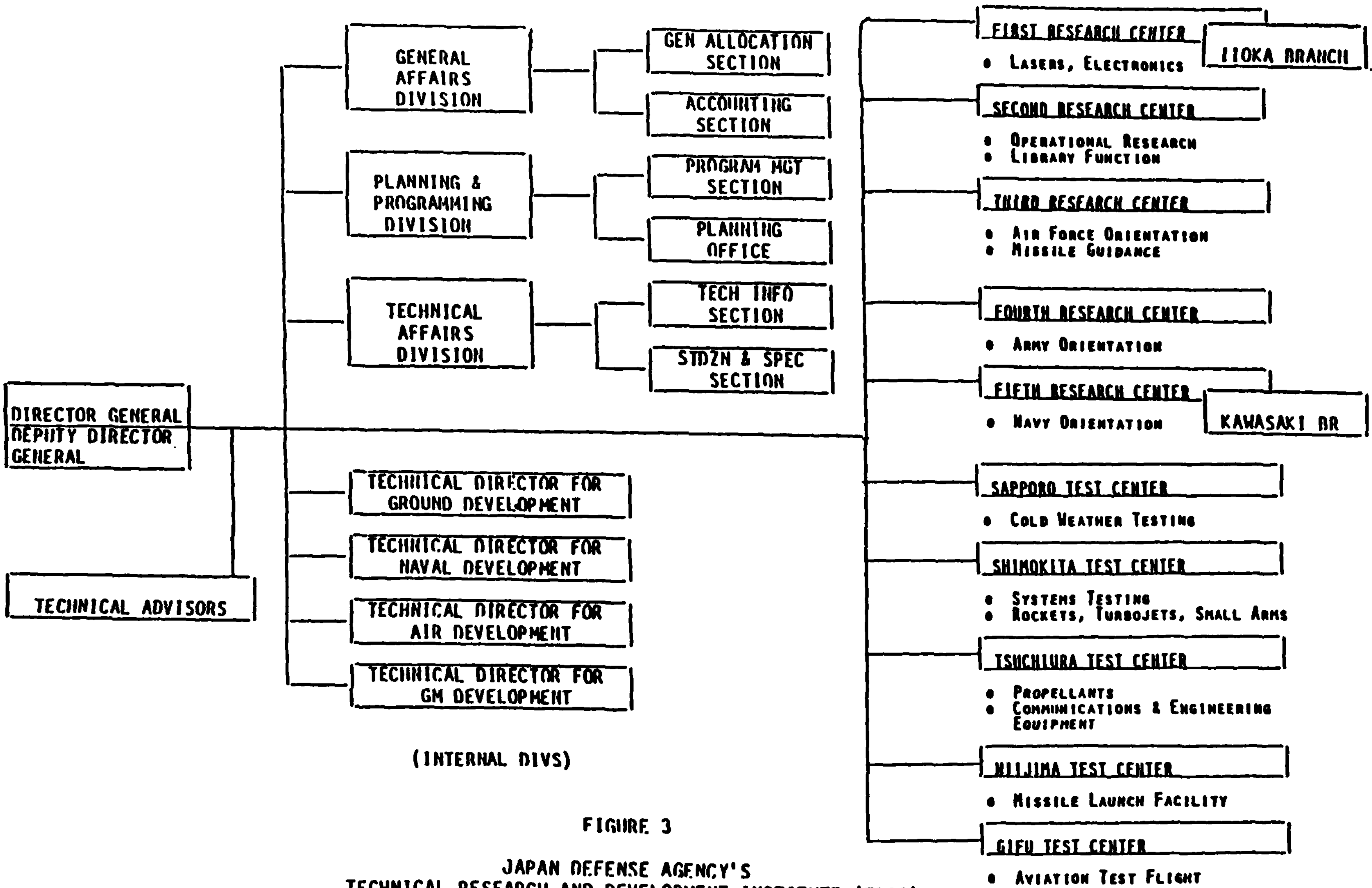

FIGURE 3

JAPAN DEFENSE AGENCY'S
TECHNICAL RESEARCH AND DEVELOPMENT INSTITUTE (TRDI)
ORGANIZATION

1.4 JAPANESE COMPETITIVENESS AND CREATIVITY

1.4.1 Japanese Industry in Transition

The Technology Team members were extremely impressed with the advanced technology base in electronics, electro-optics, opto-electronics, and millimeter- and micro-waves presently existing in Japan, and with the Japanese ability to apply this technology to the industrial/commercial/consumer sector. The Technology Team members were also impressed with how the companies visited have changed their corporate culture from that of mature, heavy industries, requiring large amounts of materials and energy to advanced information processing/communications/electronic type industries which require little imported raw material or energy. These modern technologies are consumers, as well as generators, of information. Since Japan has little indigenous natural raw material or energy resources, this transition was necessary for Japan to become an industrial power. Such a transition has also been recognized as being needed by other countries, but few have succeeded to as well as Japan has.

Achieving such a transition in approximately 15 years is a major accomplishment. It could only have been accomplished by superb technical, financial, and adminstrative management working in relatively close cooperation with government, financial, and business organizations within Japan. Technical creativity in Japan may not have led to many Nobel prizes, but considerable creativity in management, financial, and government leadership has been exercised to create this modern day miracle.

1.4.2 Scientific Creativity vs Production Know-How

The Japanese often pointed to the ability of the U.S. to make major scientific discoveries that lead to new industries. They believe the U.S. demonstrates extensive creativity. Examples cited were the laser, the transistor, and the integrated circuit. Japan has made very few major scientific discoveries in these fields, the tunnel diode being one exception that comes to mind. They believe that Japan's strong capabilities are in product development and manufacturing. This trip clearly pointed out to Technology Team members Japan's ability to improve the performance of materials and devices discovered elsewhere. Japan then engineers them into industrial/commercial/consumer products and manufactures these products at low cost. Their products enjoy performance leverage because of advances in materials and devices developed within their own laboratories or manufactured elsewhere within their vertically-integrated corporations.

Compared with U.S. research centers, a relatively small number of physicists are employed in Japanese research centers. The programs to be addressed are decided at the top management level and the decisions are handed down to be carried out. Freedom of staff to select research programs of interest to them is relatively limited.

1.4.3 The Japanese Competitive Edge

All of the companies visited by the Technology Team have a sufficient technology base to cooperate with U.S. companies for such technologies as electro-optics, communications, microwaves, and electronics. In general, they are more interested in selling products than in transferring technology to the U.S. They frequently stated that such a transfer is not practical because of the large amount of "know-how" required in such a transfer. They call such know-how, "software", which is a different interpretation of the word from that commonly used in the U.S. Since the transfer of know-how is better done by transfer of talent (i.e., people) than by the transfer of knowledge from one person to another, they consider the process, which is seldom utilized in Japan, difficult if not impossible.

Japan's ability to concentrate advanced electronic technology in the industrial/consumer/commercial sector without having to invest heavily in military weapon systems has made Japan a high-technology powerhouse among the world's nations. Their concentration on development of new products utilizing the latest technologies pioneered initially by the rest of the world -- with little investment in basic research on their part -- has contributed greatly to their rapid rise as an industrial power.

1.4.4 Japanese Management Style

Most Japanese companies visited had a policy of rotating staff out of their research laboratories on through product development and manufacturing, thereby populating their entire organization with technically creative people. In the U.S., manufacturing engineering is not considered as desirable a career as applied research or product development.

The Japanese companies visited appeared to make much more extensive use of technical people in their upper management structures than U.S. companies. Japan does not have schools of business in their university structures. The number of lawyers in Japan is extremely low in comparison with other countries. The extensive population of engineering-trained people throughout their management structure may be responsible for their appreciation for the high performance leverage that high-technology components provide their products and the competitive advantages such leverage can provide.

The extensive population of technically-trained managers throughout the large Japanese companies visited is probably responsible for the considerable effort Japanese companies put into publishing their work in professional journals and presentations at professional societies meeting both in Japan and throughout the world. They also have a strong drive in applying for patents. Most of the companies visited proudly reported numbers of publications, patents, and presentations published, granted, and given by their staff.

Japanese top-level management devotes considerable time to deciding which research areas are to be pursued within their reseach centers, as well as in assigning priorities. In most cases, a centralized Research Board, consisting of top corporate, division, and research management, meets to decide on research programs to be pursued and on priorities for such programs.

All of the companies visited had a centralized research center, a product development center, and manufacturing research/development centers. In some cases, portions of the centralized research centers were situated within the manufacturing organizations that the portions served.

The Technology Team members concluded that little really basic research is supported within the centralized research centers of the large Japanese companies visited. There was also an expression of concern that Japan has not generated great scientific discoveries as generated by the U.S. Compared with U.S. industrial labs, a relatively small number of physicists are employed by the industrial labs within Japan. Compared with U.S. industry, Japanese industry has relatively little tolerance for the "intellectual welfare" philosophy that basic researchers require. Perhaps the fundamental research activity occurs in universities which the Technology Team did not visit.

Japanese managers appear to have mastered a sophisticated long-term strategic planning process. They attempt to forecast the trends of markets and technology early. Consequently, they have moved vigorously into integrated circuits, fiber-optics, communication, computers, etc. Their decisions to transition from heavy material- and energy-intensive industries to electronic/information processing industries have made Japan a high technology and industrial world leader.

The Japanese companies visited appeared to earn considerably less net profit than U.S. companies. U.S. non-aerospace companies earning 4% to 5% of gross sales after taxes in a non-recession would be hard pressed because their stock holders can earn 10% in a savings account. Japanese companies can tolerate lower profit margin because interest rates are lower in Japan. Interest rates are believed to be lower because the savings rate is higher in Japan than in the U.S.

The eight Japanese companies visited by the Technology Team are highly diversified. Most had product lines in a number of the following fields: transportation, heavy machinery, construction, medical instrumentation, consumer appliances, semi-conductors, electro-optics/opto-electronics, computers, robotics, telecommunications, and defense and space programs.

They are able to carry on R&D, product design, and manufacturing development for a large number of products in a diversity of fields. The Technology Team members were impressed by the fierce competition among the Japanese companies. Nearly all of the companies visited had programs in compound semi-conductors, fiber-optics, computers, and robotics.

The companies visited were heavily vertically integrated. They also have product lines in component areas which obviously had a small market. Large U.S. companies, in general, would not be bothered with such components.

The U.S. enjoys the benefits of a large number of small high-technology companies to address such component markets. All of the companies visited had in-house integrated circuit (IC) facilities to manufacture specialized ICs for their own products, even when they do not compete in the IC vendor global market. They also demonstrated an interest in, and sensitivity for, their customer needs. This understanding is ultimately their key to success.

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2.0 JAPANESE R&D ACTIVITIES IN ELECTRO-OPTICS AND MILLIMETER-WAVES

2.1 GOVERNMENT R&D

The Technology Team visited two TRDI research centers. The primary activities of interest are described below.

2.1.1 TRDI's 1st Research Center

1st Division	- Basic studies in mathematical physics and aerodynamics.
	- Research on fuels and lubricating oils, polymers, steels and other metals
	- Operates digital computer system of TRDI
2nd Division	- Research on firearms (small arms, mortars, howitzers, rocket launchers, ammunition, and fire control systems)
3rd Division	- Research on hydrodynamics of propulsion stability, strength of welded structures, ship vibration and noise reduction, marine engines, and navigation instruments
4th Division	- Research on radio communications, defense communication networks, special communications, information processing equipment, electrical power equipment, and radio navigation equipment
5th Division	- Research on radar, electronic warfare, laser, and night vision/IR systems
Iioka Branch	- Research on radio wave propagation, and radio wave and electricity standards and measurements

This Center, located in Tokyo, performs research across a spectrum of disciplines as shown above.

2.1.1.1 Forward Looking Infrared (FLIR) and Night Vision Devices

Several generations of night vision devices were observed at the Center: (1) a near-IR active system (circa 1960-1964); (2) an image intensifier based upon a fiber-optically-coupled approach (circa 1970-1974), identified as their first generation of image intensifiers. There was no indication of future plans in the area of image intensification, e.g., microchannel plate work or Gallium Arsenide (GaAs) photocathode activity.

A videotape was shown of imagery generated by a first-generation FLIR system. Although the system generating the imagery was about 8 years old, the imagery of ships was clean and free of banding, generally similar in quality to U.S. first-generation FLIR imagery. No detailed information on the performance of the FLIR system was given. JDA's plans for next-generation FLIR systems include both hybrid and monolithic HgCdTe linear arrays. It was too early in the development phase, however, for them to choose one approach over the other.

Considerable applicable FLIR technology appears to reside or be in development on the industrial side.

2.1.1.2 Tunable Laser Sources

Projects at the Center stressed multiple-wavelength laser-pulse generation for laser radar. Similar applications have been studied within the U.S. over the last 15 years.

Tunable sources are being studied at the Center with Nd:YAG and dye lasers, and nonlinear optical techniques. There is ongoing work to obtain dye laser radiation out to 1.36 microns. Dr. K. Kato, a well-known researcher i.. tunable sources, has published extensively. He is rapidly making use of recent research results in tunable sources and non-linear optical crystals.

2.1.2 TRDI's 3rd Research Center

- 1st Division - Aviation-platform guided missiles (aerodynamic performance, stability/operability, structural strength)
- 2nd Division - Jet engines, fatigue in rocket propulsion engines
- 3rd Division - Instruments, radio wave devices, image/optical guidance environmental testing, and missile tests

This Center, located near Tokyo, concentrates in aviation and missile research in three divisions as delineated above.

2.1.2.1 Fiber-Optic Gyros

Three approaches are under consideration: (1) Homodyne method (line sensor), (2) frequency modulation, and (3) optical heterodyne concepts. Their goal is a large-dynamic-range gyro for military applications. They are using a Gallium-Aluminum-Arsenide (GaAlAs) diode laser with a single-mode, polarization-preserving fiber. Several models have been built in compact packages. Japanese researchers were encountering the same problems with thermal stability of the laser as those encountered in the United States Air Force (USAF) Fiber-Optic Gyro (FOG) program at a U.S. manufacturer, forcing a change to super-radiant diodes. Craftsmanship appears to be excellent for this early stage of development.

2.1.2.2 Missile Guidance

Testing of an IR missile seeker has been completed and the seeker is ready for production with target performance alleged to be twice that of a similar U.S. system. A semi-active radio frequency (RF) seeker was also observed. This monopulse seeker is in R&D. It was not known whether Doppler signal processing is utilized.

Missile seekers under development use currently available technology. In the area of IR signal processing, a demonstration was given in imagery processed by a desk top computer. Various algorithms for tracking and image dissection are being studied. A centroid tracker algorithm was demonstrated although practical implementation had not been carried out. Techniques for employing internal detail and advanced segmentation were just beginning to be studied.

2.1.2.3 ASM-1 Sea Skimming Anti-Ship Missile

The missile, now in production and in the Japanese inventory, is the result of a 6-year design-to-price R&D program begun in 1973. The total cost of design and development of the missile system was $50 million (testing not included). Mitsubishi was the prime contractor.

The ASM-1 is launched from an airborne fighter platform. Missile guidance can be achieved through monostatic active homing from the radar on the ASM-1. The overall impression given by the Japanese is that the ASM-1 is a superior sea-skimming missile.

Of particular interest to the Technology Team was the development and acquisition process which resulted in a low R&D cost ($50 million) and fast development cycle. This R&D/acquisition process of essentially two phases is being used as a model for future missile programs proceeding from exploratory to engineering development.

2.2 INDUSTRY R&D

The Technology Team surveyed eight Japanese companies involved in electro-optic and millimeter wave research and development. Some activities of interest to the Team which were observed or discussed during the visit are given in Figure 4.

COMPANY VISITS

NEC

- Field-Effect-Transistor (FET) Development
- Millimeter- and Micrometer-Wave Monolithic Integrated Circuits (ICs)
- Millimeter-Wave Diodes
- Electro-Optics
- Millimeter-Wave and Microwave Tubes
- Fiber-Optic Gyros

HITACHI

- Optical Disk Technology
- Semiconductor Lasers
- Optical Fiber Technology
- Fiber-Optic (FO) Data Links
- High-Resolution TV Cameras

FUJITSU

- Local Area Network (LAN) and Components
- Millimeter-Wave Doppler Radar
- IR CCD Imaging
- Phased-Array Antenna for Radar

MITSUBISHI

- 94 GHz Missile Seeker and Millimeter-Wave Components
- Optical Fire Control System
- Missile/Anechoic Chamber Simulator Facility
- Millimeter-Wave Radiometers
- Carbon Dioxide (CO_2) Lasers

TOSHIBA

- Gas Lasers
- Microwave and Millimeter-Wave Semiconductor Devices
- Direct Broadcast Satellite (DBS) Receivers
- Visible CCD
- GaAs Lasers for Optical Storage Disks
- Integrated Optic Spectrum Analyzer (IOSA)

SHARP

- DBS Receivers
- Visible Semiconductor Lasers
- Eraseable High Density Optical Storage

SUMITOMO

- GaAs Production Technology
- Optical Fiber Communications
- Fiber-Optic Gyro (FOG)

MATSUSHITA

- Optical Storage Disks
- Sensors
- High-Q, High-Dielectric-Constant Materials for Filter Miniaturization and Frequency Stabilization with Temperature
- DBS Downconverter Development and Production
- Optical Devices
- Optical Fiber Communication

FIGURE 4

2.2.1 Nippon Electric Company (NEC)

FY 83 Gross Sales:	$7 Billion
Growth Rate:	18% Per Year
Employees:	79,000

Product Lines

Digital Switching Systems
Fiber Optic Communications
Satellite Communication Earth Stations
Computers (Supercomputers, Personal Computers)
Electron Devices (GaAs, FET, VLSI, Hybrid ICs, CCDs)
Home Electronics (TV, VTRs, Radio Receivers, etc.)

Topics covered included electro-optics, image sensors and millimeter-wave devices, optical and millimeter-wave applications, micro- and millimeter-wave tubes.

2.2.1.1 Field-Effect-Transistor (FET) Development

- High Electron Mobility Transistors (HEMT)

  NEC is developing a GaAlAs/GaAs two-dimensional electron gas (TDEG) FET for low-noise amplifier applications at microwave and millimeter-wave frequencies.

- Metal-Insulator-Semiconductor-Field-Effect-Transistors (MISFET)

  NEC is also developing an InP MISFET. This device uses a U-shaped SiO_2 insulating layer and a self-aligned gate.

2.2.1.2 Millimeter- and Micrometer-Wave Monolithic Integrated Circuits (ICs)

NEC is developing microwave monolithic GaAs ICs for direct broadcast satellite (DBS) reception. This unit consisted of four chips.

NEC is also developing a 28-GHz medium-power monolithic GaAs Metal-Semiconductor-Field-Effect Transistor (MESFET) amplifier.

2.2.1.3 Millimeter-Wave Diodes

- Si IMPATT

  A series of double-drift Si Impact Avalanche and Transit Time (IMPATT) diodes in diamond heat sink packages covering frequencies up to 94 GHz is being produced. They are suitable for both continuous wave (CW) and pulsed operations. Mean-time-to-failure (MTTF) of 10^7 hours is predicted at 210°C junction temperature.

- GaAs IMPATT

  Single-drift p-n junction read structure IMPATTs are available on a commercial basis.

- GaAs Schottky Barrier Diodes

  Schottky barrier mixer diodes are being produced. NEC also manufactures beam-lead mixer diodes.

2.2.1.4 Electro-Optics

NEC has constructed a XeCl laser for photochemical depositions of thin-film materials for integrated circuits. The super-radiant nature of excimer lasers reduces the speckled noise and interference effects problems that would be obtained with less spectrally coherent sources. Coupled with their brightness in the ultraviolet region, this feature makes them strong contenders for replacing existing arc-lamps in integrated circuit photolithographic instrumentation. A presentation of optical semiconductor devices such as laser diodes was given.

- Integrated-Optics Signal Processing

  NEC has developed an acousto-optical integrated optics time-integrating correlator. A sketch of a modified version of this device was shown. NEC has also developed an acousto-optical frequency-translator for frequency-modulation method fiber-optic gyros.

2.2.1.5 Millimeter-Wave and Microwave Tubes

NEC is developing a full line of traveling wave tubes (TWTs), klystrons, gyrotrons, and magnetrons for radar, satellite communications, and plasma physics applications. Tubes span the frequency range from 500 MHz to 53 GHz. The millimeter-wave gyrotron has a possibility of application to millimeter-wave radars.

2.2.1.6 Fiber-Optic Gyro

NEC has three types of fiber-optic gyros under development. The first approach, a phase-modulation concept, uses a super-radiant diode laser at 0.85-micron and a Si photodiode detector. Phase modulation is implemented by a loop of the fiber wrapped around a piezoelectric cylinder. In the future, they are going to implement the approach with better super-radiant laser diodes.

The second approach, a frequency modulation concept, uses integrated optic $LiNbO_3$ AOM. An InGaAsP laser diode and a Ge Avalanche Photo Diode (APD) detector are used.

The third approach is an optical heterodyne concept. An InGaAsP laser diode is used to generate the two counter-propagating beams. A Ge APD detector is used in the detector arm. A prism polarizer is used with a thin film partial mirror for coupling into and out of the fiber. Their present goal is improving accuracy.

NEC is pursuing the fiber-optic gyro development due to the strong interest by the auto industry. They have compared the development potential for fiber-optic gyros using miniature bulk and integrated optics components.

2.2.2 Hitachi

FY 83 Gross Sales:	$16.4 Billion
Employees:	155,582

Product Lines

Power Generation and Transmission Equipment
Home Appliances
Computers
Home Electronics and Communication Equipment

The Technology Team visited the Hitachi Central Research Lab in the Kokubunji section of Tokyo. The topics covered included fiber optics communications systems and devices, laser diodes, metal oxide semiconductor (MOS) solid-state imagers, magnetic bubble memory, and optical recording technology.

Hitachi has work in progress on fiber optics components for communications. It is the first company to produce a commercial single-chip MOS visible imager in large quantities. It also produced the first solid-state color TV camera based on a MOS single chip which is marketed by RCA in the U.S. It has also done work in 1.55 micron distributed feedback (DFB) lasers and quantum well devices (GaAlAs).

2.2.2.1 Optical Disk Technology

Hitachi has developed an optical disk with a high storage capacity.

2.2.2.2 Semiconductor Lasers

Hitachi's laboratory uses three crystal growth techniques - Liquid Phase Epitaxy (LPE), Metal Organic Chemical Vapor Deposition (MOCVD), and Molecular Beam Epitaxy (MBE). Two basic development efforts were noted. The first is a high quality 1.55 micron DFB laser for telecommunications. It is a buried heterojunction structure.

The second effort features a GaAlAs multi-quantum well (MQW) active layer grown by MOCVD. These devices are ready for production.

2.2.2.3 Optical Fiber Technology

Hitachi is developing Ge-Se chalcogenide glass infrared optical fibers. Material development and evaluation has been carried out. Studies of the transmission change with relative concentrations of Ge, Sb, and Se have been made. Progress has been made resulting in a few dB loss per meter at 10.6 micron. This capability is at least partly due to the very high purity starting materials.

Hitachi has investigated Ge-Se chalcogenide glass fibers. The analysis indicates that the addition of Sb to Ge-Se chalcogenide glass should yield fibers with a very small absorption loss coefficient. The work is progressing to obtain even lower losses.

Hitachi is working on single-mode polarization-preserving fibers with an elliptical jacket cross-section to lift propagation degeneracy.

2.2.2.4 Fiber Optic (FO) Data Links

Hitachi is working on FO links intended for:

- Broad-band telecommunications
- Electrical power industry
- Computer industry.

2.2.2.5 High-Resolution TV Cameras

Hitachi develops and produces a variety of TV cameras, components, and imagers. These include:

- A small, compact, portable TV camera weighing less than 1 kilogram (commercially available).
- A 1/2-inch Saticon tube.
- A single-chip MOS TV camera.

Hitachi has evolved the MOS imager into a successful commercial product. The current MOS imager is a second-generation design and is in large-scale production. A third-generation MOS imager with improved performance has been transitioned from the research laboratory to production. Full-scale production is expected by the end of the year.

2.2.3 Fujitsu

FY 83 Gross Sales:	$4.0 Billion
Employees:	53,000

Product Lines

- Data Processing
- Telecommunications
- Semiconductor and Electronic Components

The Technology Team visited the Fujitsu Laboratory, Kanagawa. Topics covered included GaAs devices (including logic, memory, HEMT, and VLSI) and opto-electronics (Ge PIN, III-V PIN, and diode lasers).

Fujitsu has a major commitment to development of GaAs to perform high-speed logic functions. A secondary objective is to develop components, particularly lasers and detectors. Fujitsu's technological strengths are GaAs HEMT and 1.3 micron DFB Lasers.

2.2.3.1 Local Area Network (LAN) and Components

Fujitsu is developing a short-range (2-4 km) millimeter-wave communication system for local use.

2.2.3.2 Millimeter-Wave Doppler Radar

Fujitsu is designing a Doppler radar for automobile collision-avoidance use. It was indicated that the radar must be low cost and reliable. The item is not in production because Japanese automobile manufacturers have yet to complete their market evaluation.

2.2.3.3 IR CCD Imaging

Fujitsu demonstrated an infra-red imaging TV using an IR charge-coupled-device (CCD) detector array fabricated from HgCdTe. The image scenes displayed were high-quality night-time scenes of various targets and backgrounds.

2.2.3.4 Phased-Array Antenna for Radar

Fujitsu has been developing a phased array antenna for radar applications.

2.2.4 Mitsubishi Electric Corporation (MELCO) (U)

FY 83 Gross Sales:	$6.5 Billion
Employees:	48,291

Product Lines

Communication Systems	Heavy Machinery
Radar and Guidance Systems	Industrial Products
Computers	Consumer Products
Semiconductors	

The Technology Team visited MELCO's Kamakura works. The topics covered included electro-optic systems and subsystems, such as seekers and trackers, and electro-optic components such as Focal Plane Arrays (FPAs), Fiber Optics (FOs), Optical Signal Processors (OSPs), and lasers. Millimeter-wave systems and subsystems, as well as millimeter-wave components, were discussed.

Mitsubishi's efforts were focused on heavy electrical machinery and have been quickly and effectively moving into the electronics field. The Kamakura works has the heaviest concentration of defense products (80%) of any of the organizations visited. They have an extremely thorough technical assessment and developmental approach to systems. The considerable defense activity at Mitsubishi is focused on system development as well as component development.

2.2.4.1 94 GHz Missile Seeker and Millimeter-Wave Components

MELCO has been developing a 94-GHz missile seeker. It is an active radar consisting of an IMPATT transmitter, a Gunn local oscillator (LO), a balanced mixer, an intermediate frequency (IF) amplifier, a circulator/duplexer, a dish antenna, and associated circuits.

MELCO is also developing monopulse antenna feeds, Gunn local oscillators, IMPATT oscillators, mixers, circulators, single-pole-single-throw (SPST) switches, and single-pole-double-throw (SPDT) switches as candidates for future missile systems, attempting to build in-house capabilities for key millimeter-wave components.

2.2.4.2 Optical Fire Control System

MELCO has built an active/passive optical system to test the viability of several optical concepts for acquisition and tracking for a fire-control system (generally for a ground-based fire control system). Full implementation, fabrication, and operation have not been realized yet.

This system will enable MELCO to gain experience in optical fire control systems in order to test the best combination of devices and features for future system applications.

2.2.4.3 Missile/Anechoic Chamber Simulator Facility

MELCO has a very modern missile simulator laboratory consisting of hybrid computers, real missile RF heads, and an anechoic chamber. Missile and target trajectories were plotted in real time on a novel light-emitting-diode (LED) display having 102,400 LEDs (colors were yellow, red, green and orange).

2.2.4.4 Millimeter-Wave Radiometers

MELCO has developed a series of radiometers covering frequencies from 22 GHz to 115 GHz for a radio astronomy telescope. The radiometers are mounted on a 5-element array of 10 meter diameter antennas. Mixers, local oscillators, orthomode transducers, dual-mode horns, and rotary joints have been developed in-house. MELCO is currently developing radiometers for a spacecraft to be launched in 1986. MELCO is capable of delivering space-qualified millimeter-wave hardware.

2.2.4.5 Carbon Dioxide (CO_2) Lasers

In addition to large CO_2 lasers being used for material processing and machining in industrial applications, MELCO has developed a sealed CO_2 TEA laser.

2.2.5 Toshiba

FY 83 Gross Sales: $10.4 Billion
Employees: 103,000

Product Lines

Consumer Products (30%)
Heavy Duty Electrical Products (29%)
Electronic Components, Industrial Electronics (30%)

Integrated Circuits	Displays
Opto-electronics	PCBs
CRTs	Microwaves

Materials, Machinery, etc. (11%)
Fiber Optics

The Technology Team visited the Komukai Science Institute in Kawasaki. The topics covered included:

- Charge Coupled Devices
- Fiber Optics
- Optical Processing
- Gas Lasers
- Solid-State Sources
- Semiconductor Devices
- Receiver Control Devices

Toshiba has developed a 256K dynamic random access memory (DRAM). They are a world supplier of 64K DRAMs, color TV tubes, and large gate arrays (20,000 gates). They are active in office automation, local area networks, and personal computers. Toshiba was the principal contractor for Japan's National Space Development Agency for the Engineering Test Satellite.

2.2.5.1 Gas Lasers

The gas laser and associated optics work at Toshiba is performed in the Manufacturing Engineering Lab. The work is directed toward material processing for enhancing productivity of their manufacturing as well as instrumentation and sensing of the manufacturing process. They also sell lasers to other companies in Japan for the same general purposes.

The Manufacturing Engineering Lab of Toshiba manufactures YAG, CO_2 He-Ne, Ar lasers, and laser diodes both for internal use and for sale. YAG lasers, for example, used for welding of cathode ray tube (CRT) gun parts, increase productivity as well as image performance. CO_2 lasers in the 1 to 5 kW continuous wave range are used for material cutting and welding and pulsed TEA CO_2 lasers for marking semiconductor components parts. Low-power units (500 W and below) have been mostly imported and are used for sheet metal cutting and other non-metal processing applications.

This presentation also included information on diamond turning machines for machining mirrors. They have used their diamond turning machines for fabricating Cu, Al, Ni, plastics, Ge, Si, and KDP optical surfaces.

2.2.5.2 Microwave and Millimeter-wave Semiconductor Devices

The following semiconductor devices are examples of products being developed at Toshiba.

- <u>Power Devices</u>

  In the processing of power MESFETS, ion-implantation of the active layer is used with aluminum gate metallization (passivated by SiO_2 layered over the metal and device surfaces up to inner edges of source and drain).

- <u>Low-noise Devices</u>

  HEMT devices are under development. HEMT devices provide improvement in noise figure compared to low-noise FET performance along with associated improvement in gain.

2.2.5.3 Direct Broadcast Satellite (DBS) Receivers

Toshiba is developing 12 GHz DBS receivers. The receivers consist of a 3-stage low-noise-amplifier (LNA) with single voltage supply requirement, a bandpass filter, a FET Dielectric Resonated Oscillator (DRO), a balanced mixer, and an IF preamp.

2.2.5.4 Visible CCD

Toshiba has designed a camera for the industrial closed circuit television market utilizing an interline transfer CCD array. The CCD array is shifted horizontally 1/2 pixel during the blanking period between each field, so that the number of pixels in the horizontal direction is doubled. The shift is electromechanical, based upon a bimorphic piezoelectric element. This approach solves the low resolution and aliasing problems caused by the low fill factor in the horizontal direction.

2.2.5.5 GaAlAs Lasers for Optical Storage Disks

Toshiba is studying the use of a GaAlAs diode laser for both reading and writing on optical disks. At useful write rates, it takes more than 5 mW of power to create pits in the storage medium. Less power is required for reading the disk. However, the laser must have certain mode characteristics to prevent instability if strong reflections are fed back to the laser.

Toshiba has created the "Embedded Confining Layer on Optical Guide" or ECO structure to meet these requirements. They perform a two step MOCVD crystal growth to achieve the required quality in crystal growth on the p-type GaAlAs guide layer (exposed by etching through the n-type GaAs current blocking layer).

2.2.5.6 Integrated Optic Spectrum Analyzer (IOSA)

The company is carrying out experimental development of an IOSA. The components for the IOSA include the following:

Substrate:	$LiNbO_3$
Lens:	Aspherical geodesic
Bragg cell:	Tilted finger with non-linear FM chirp
Laser:	GaAlAs double heterostructure LD
Detection:	Butt coupled, CCD readout.

The performance of this device is limited by lens design and waveguide quality.

2.2.6 Sharp Corporation

FY 83 Gross Sales:	$3.2 Billion
Employees:	50,000

Product Lines

Electronic Products - Consumer and Information Processing

The Technology Team visited the Engineering Center and the Industrial Instruments Center, both in Nara. Topics covered included:

- Automated Assembly Lines for Calculators
- DBS Receivers
- Si and GaAs Solar Cells
- EL Displays.

Sharp is developing DBS receivers using monolithic microwave IC chips. Sharp also has optical data storage capability in development, including an eraseable version. They have developed GaAs solar cells with 22% efficicency for space application.

2.2.6.1 DBS Receivers

DBS receivers have been developed using three hybrid chips. The receivers will be assembled by conveyer assembly lines at first, then the assembly lines will be gradually automated.

The flexible assembly line concept used for calculators appears adaptable to production of microwave/millimeter-wave hardware.

2.2.6.2 Visible Semiconductor Lasers

Sharp has a 10-mW visible laser diode (LD) available commercially, emitting in the 7700-7900 Å spectral region with a threshold current of 50 ma in a TE_{00} optical mode. Recently, the output power has been increased to 30 mW. The device is grown by LPE. The structure of the LD is VSIS (V-channel Inversion Strip). The special structure and the high material quality enable high power at the subject wavelength. This type LD is of value in optical processing and recording.

2.2.6.3 Erasable High Density Optical Storage

An erasable optical disk high-density storage device has been developed by Sharp. The parameters were said to be substantially the same as for the DRAW (Direct Read After Write) standard disk. The system is being designed for office storage.

2.2.7 Sumitomo Electric

FY 83 Gross Sales:	$1.7 Billion
Employees:	11,900

Product Lines

Electronic Products and Materials

The Technology Team visited the Itami and the Osaka Works. Topics covered included:

- III-V Compound Semiconductor Materials
- Synthetic Diamonds for Optical Windows and Heatsinks
- Ceramic for Packaging, Filtering and Micro Integrated Circuits
- MgF_2 Windows
- TP-CVD (Fusion Reactor Wall)
- Optical Fiber Cable
- Optical Data Link
- Fiber-Optic Gyroscope
- CAD/CAM

2.2.7.1 GaAs Production Technology

Sumitomo supplies a major portion of world GaAs wafer requirements (30,000 wafers/month). They currently produce two- and three-inch diameter wafers. Five-inch wafers are under development.

Sumitomo uses both the horizontal Bridgeman (HB) and liquid encapsulated Czochralski (CZ) (LEC) methods in their production facilities.

Three grades of GaAs wafers are sold on the world market. The etch pit density of the wafers is typically $10^4/cm^2$ with carrier concentrations of 10^5-$10^{19}/cm^3$. Sumitomo has recently announced 0-defect substrates. They expect to ship sample quantities by the end of the year.

Using the CZ method, Sumitomo has grown a 3-inch diameter BSO single crystal 7 kg in weight.

2.2.7.2 Optical Fiber Communications

Sumitomo's cable capabilities are well-known in the United States. Marine cable is one product representative of other commercial cables. Fiber is drawn using Vapor Axial Deposition (VAD) with pre-form glass ingots. Multiple fibers are combined with electrical conductors and steel strength members to create the final cable (hermetically sealed marine use). They have developed splice kits (< 0.1 dB) and other paraphernalia utilized in this product line area.

LAN systems will be built in the 30-200 MBPS data transmission rate range.

2.2.7.3 Fiber-Optic Gyro (FOG)

A fiber-optic gyro is under exploratory development for applications such as robotics.

2.2.8 Matsushita

FY 83 Gross Sales: $16.9 Billion
Employees: 124,825

Product Lines

Video Equipment
Audio Equipment
Home Appliances
Communication and Industrial Equipment
Energy and Kitchen-Related Equipment
Electronic Components

The Technology Team visited the Central Research Laboratory in Osaka. Topics covered included:

- Sensor Technology
- High-Resolution Display Technology
- Communication Components
  - Opto-electronic Devices
  - SAW Devices
  - Microwave Components
- Optical Fiber Communication Technology
- Optical Recording Technology

2.2.8.1 Optical Storage Disks

Their system uses TeO_x where x 1 with tellurium suboxide formed from Te/TeO_2 mixtures. In the permanent storage case, the reflectivity is modified by focusing laser power to create a temperature increase pulse. An eraseable storage medium requires the addition of Ge or Sn as a dopant. Matsushita has developed an erasable optical storage device which can be cycled for 10^6 erasures.

2.2.8.2 Sensors

Matsushita is working on a variety of sensors to measure temperature, pressure, humidity, gas composition, position, radiation dose, magnetic fields, electric fields, and acoustic signals. Progress is being made on pyro-electric linear arrays, fabricated from $PbTiO_3$ for IR detections, and on a pyro-electric PVF_2 video-camera for temperature measurements. An optical sensor, utilizing temperature variation in birefringent single crystals, is being developed.

Work is in progress on fiber-optics current and voltage sensors using the Faraday and Pockel effect, respectively. For low-current detection, a mixed rare-earth iron garnet crystal is used. For high current, ZnSe crystal is used. The voltage sensor uses $LiNbO_3$ and measures voltage from 0.05 V to 200 V. Light from a fiber is incident on the Z-face and the two opposite Z-faces have transparent electrodes which are shorted to eliminate the disturbance of the pyro-electric effects.

2.2.8.3 High-Q, High-Dielectric-Constant Materials for Filter Miniaturization and Frequency Stabilization with Temperature

Matsushita is developing a ceramic dielectric material with low loss at microwave frequencies. This material has been used to produce compact duplexers and bandpass filters for land-mobile radio equipment. The high dielectric constant is needed for miniaturization of components. This material has also been used as a dielectric resonator frequency stabilizer for the local oscillator (LO) in the DBS downconverter.

2.2.8.4 DBS Downconverter Development and Production

Matsushita has developed and is already marketing 12-GHz DBS receivers both in Japan and the U.S. The unit contains 2 RF amplifier chips; 1 LO chip; 1 mixer chip, and 4 silicon chips for the IF amplifier.

2.2.8.5 Optical Devices

An acousto-optical Bragg deflector is being developed with a 3500 Å single-crystal Zn compounds on sapphire substrate. The device appears to be very narrow banded. Work is underway on monolithic integration of laser sources, photodiode detectors, switches, and preamps for communications systems.

2.2.8.6 Optical Fiber Communication

Matsushita is producing optical fiber communication systems for commercial applications such as:

- Multichannel Transmission of VHF Analog TV Signals
  - Input signal - VHF band TV signals
  - Operating wavelength - 1.3 micron LD
  - Transmission distance - 4 km

- An Optical Transmission System for High Definition TV.
  - A/D converter for each of three color signals
  - Electronically multiplexed

3.0 FINDINGS AND CONCLUSIONS

The Electro-Optics and Millimeter-Wave Technology Team was successful in initiating dialogue on technology exchange with Japanese government and industry. They found all government and industry organizations to be very receptive to their visit and very interested in developing cooperative programs in electro-optic and millimeter-wave technologies, as well as other areas.

The Team observed that industrial and commercial interests drive 90-95% of all Japanese electro-optic technology. Millimeter wave technology is driven to a lesser extent by commercial interests. This commercial motivation will necessitate extensive cooperation between the U.S. government and the Government of Japan to effectively interact with individual Japanese companies. (See Figure 5.) Several U.S. industries are interested in Japan's very effective management techniques to transition technology from R&D to engineering and manufacturing for large scale production. The exchange of technology would provide improvements in system development for U.S. and Japanese products.

The findings on electro-optics and millimeter-wave technologies are described in Sections 3.1 and 3.2 and detailed and summarized in the matrix of Figure 6. The marks (Xs) in Figure 6 represent technologies observed or described in literature provided during company visits.

3.1 MILLIMETER-WAVE AND MICROWAVE TECHNOLOGIES

3.1.1 *Gallium-Arsenide Materials*

Microwave and millimeter-wave quality gallium-arsenide (GaAs) materials are being produced and marketed in Japan. Five-inch-diameter wafers are under development, and current two- and three-inch-diameter wafers have defect densities typically $1x10^4/cm^2$ to as low as $2x10^2/cm^2$. Sumitomo produces over 30,000 microwave-quality GaAs wafers per month. This rate of production meets almost all of Japanese needs and more than half of worldwide needs.

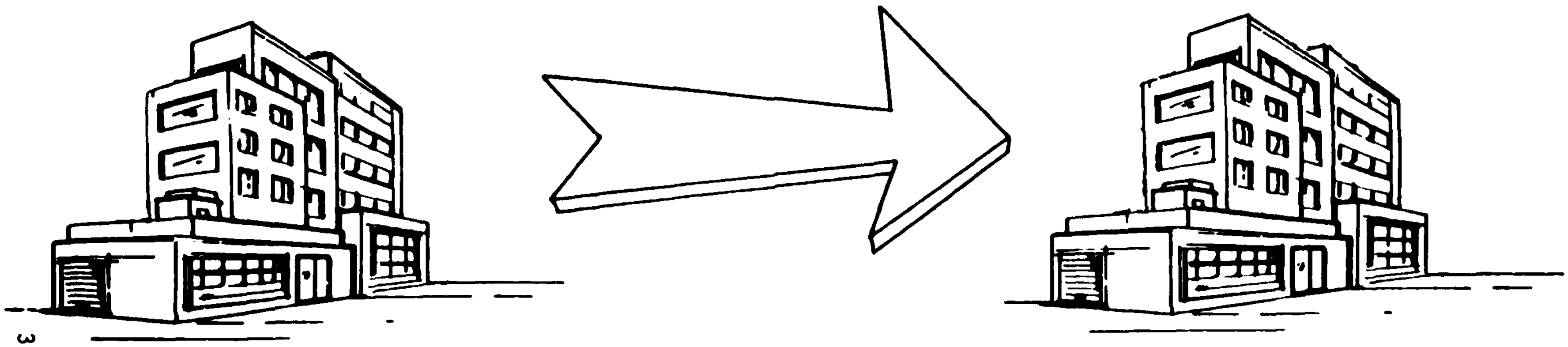
GaAs materials are used in microwave and millimeter-wave FET devices, mono-lithic integrated circuits, and high-speed digital integrated circuits.

3.1.2 Devices and Components

The Japanese are actively engaged in the design, development, processing, and production of low-noise power FET devices up to 50 GHz. Several Japanese companies are in basic research and development phases on high electron mobility transistor devices. Japanese electronics companies have also produced IMPATT oscillators, Gunn local oscillators, antenna feeds, mixers, circulators, and SPST and SPDT switches suitable for microwave and millimeter-wave applications at engineering development levels.

JAPANESE INDUSTRY

U.S. INDUSTRY



MECHANISMS

- Government (DOD/JDA) Data Exchange
- License to Manufacture
- Transfer Know-How
- Privileged Advanced High Tech Data

MOTIVATIONS

- Mutual Defense Technology Requirements
- License Fee
- Profit
- U.S. or Japan Industry gets profit manufacturing $$ by License or Subsidiary Route

FIGURE 5

INDUSTRIAL INTERACTIONS -- MECHANISMS AND MOTIVATIONS

Sites Visited by the Technology Team	MM-WAVE/μ-WAVE TECHNOLOGIES					E-O TECHNOLOGIES								
	GaAs Materials	Devices and Components	Systems	Active Apertures	DBS Receivers	Lasers	Optical Processing	Optical Data Storage	Visible Imager	Infrared Imager	Visible Night Vision Devices	LAN Components	Fiber Optic Gyros	Displays
TRDI #1						X			X	X	X			
TRDI #3		X	X	X						X			X	
NIPPON ELECTRIC COMPANY		X	X		X	X	X		X	X			X	
HITACHI					X	X		X	X	X		X		
FUJITSU	X	X	X		X			X		X		X		X
MITSUBISHI ELECTRIC COMPANY		X	X	X	X	X			X	X	X	X		X
TOSHIBA		X	X		X	X	X	X	X	X		X		
SHARP		X			X	X		X						
SUMITOMO	X	X				X						X	X	
MATSUSHITA		X	X		X	X	X	X	X			X		

FIGURE 6

ORGANIZATION/TECHNOLOGY MATRIX

These devices and components are being used more frequently in local area networks (LANs), Doppler and collision-avoidance radar, direct broadcast satellites, and radio astronomy.

3.1.3 Systems

Several important millimeter-wave and microwave systems are being developed in Japan. Radio astronomy (22-115 GHz) receivers and weather satellite efforts are in planning phases. X-band active-aperture seekers, IMPATT transmitter seekers, and 50-GHz local area networks are all in engineering development at various companies.

3.1.4 Direct Broadcast Satellite Receivers

Many of the electronics companies in Japan are currently marketing or plan to market DBS receivers. A high level of manufacturing automation is expected to produce high-volume, low-cost 12-GHz receivers. A monolithic integrated circuit approach is ready for transitioning into mass production.

3.2 ELECTRO-OPTIC TECHNOLOGIES

3.2.1 Lasers

All of the Japanese companies visited had extensive programs in laser diodes, and the quality of the technology was outstanding. Work was being done in CO_2, XeCl, YAG, lead salts, and Er:glass lasers. Programs existed in CO_2 lasers and YAG for material working, with moderate to little activity in Er:glass, lead salts, and XeCl lasers. Good work was being done in CO_2, XeCl, and lead salt lasers.

Laser technology was being applied in video disks, audio disks, data storage, printing, FO communications, semiconductor processing, material working, pollution detection, and time-domain reflectometry.

3.2.2 Optical Processing

Optical processing work was being carried out on a time-integrating acousto-optic correlator, an integrated optic acousto-optic spectrum analyzer (IO-AOSA), and Bragg cell development. Overall, however, few of the companies visited were working in the optical processing area, and generally a low level of effort was observed. Japanese commerical applications of optical processing are in general signal processing, Bragg cells, and radio astronomy. Japan continues the integrated optics approach to AOSA.

3.2.3 Optical Data Storage

In visits to several companies, the Technology Team found work on mature, commerical, high density ($4x10^7$ bits/cm^2), and permanent (archival) optical data storage. Work was in progress on erasable, high-density, and developmental optical data storage. More than half of the companies visited had commercial products. Generally, the Team observed an excellent capability for producing commercial systems.

3.2.4 Visible Imager

The Technology Team found broadly-based multi-company efforts to develop single-chip color cameras for the world industrial and consumer marketplace. There is a major effort on linear arrays for document reading and facsimile applications. There is aggressive competition among the companies to develop a commercially viable chip. Hitachi is the first company in the world to produce a MOS camera in volume production. The depth and breadth of Japanese technology in this area is substantial. Commerical applications of the technology include high-volume, low-cost color cameras and facsimile equipment for the worldwide consumer/industrial markets.

3.2.5 Infrared Imager Technology

The Japanese are engaged in R&D work on IR detectors and arrays for domestic needs, including HgCdTe linear and area arrays, PT-SI Schottky barrier CCDs, and pyro-electric vidicons. First-rate research in HgCdTe and Schottky barrier imagers is being conducted in Japan.

3.2.6 Visible Night Vision Devices

The Japanese have done R&D work on fiber-optically-coupled image intensifiers, a low-light-level television (LLTV) imaging tracker, and active laser imaging radars (0.53, 1.06, 10.6 microns). The LLTV work is a single system built 2 years ago using French microchannel plate technology.

3.2.7 Fiber Optic Local Area Network (LAN) Component Technology

The Japanese are engaged in R&D work on components such as distributed feedback lasers at 1.3 and 1.55 microns, high-power 0.8 micron lasers, and integrated opto-electronic chips. Several companies are aggressively pursuing this topic for commercial purposes in the 30-200 MBPS range.

3.2.8 Fiber-Optic Gyro

Several companies are involved in fiber-optic gyro technology. Three approaches to the technology are: homodyne method (line sensor), frequency modulation, and heterodyne concepts. There is a development emphasis on improving accuracy. Industrial applications include autos and robots.

3.2.9 Displays

The Japanese are involved in R&D and production of electroluminescent (EL), liquid crystal (LC), and high-definition cathode ray tube (CRT) displays. They are leaders in EL and LC technology. They are the world leader in high-volume production of alphanumeric and graphic displays, and they are at the forefront in advanced imaging displays.

Commercial applications of alphanumerics include small calculators, intrumentation panels, etc. Graphics are applied in computers and map overlays, and imaging in flat panel TV sets.

3.3 SUMMARY

Japan's millimeter-wave devices and components are comparable to those made in the U.S. Gallium arsenide and other III-V materials make broadband phased-array technology possible. Electro-optic technologies of interest include high-resolution visible CCD TV cameras and color imagers for low-cost surveillance systems.

3.4 MANAGEMENT FINDINGS

Japanese industry has attained world recognition for its ability to transfer research and development results into production capabilities. Electro-optic and millimeter-wave technologies have benefited from this ability. Parallel product development and emphasis on production engineering contribute to this success and to the low cost and high quality of electro-optic and millimeter-wave materials, components, and complete systems. All of the electro-optic and millimeter-wave development and production facilities visited had outstanding management.

Electro-optic and millimeter-wave technology exchange between the U.S. and Japan presents distinct challenges. In Japan, much of the technology of interest to the U.S. is in the Japanese industrial sector. Furthermore, cultural, language, and political sensitivities are important considerations. The Japan Defense Agency (JDA) plays a primary role selecting companies for production of defense equipment and in formulating technology transfer for technologies developed for, and, therefore, owned by the Government. The Ministry of International Trade and Industry (MITI) is in charge of coordinating R&D policies for the technologies owned by the commercial sector and in regulating overseas technology transfer of them. An excellent working relationship between MITI and JDA personnel is a necessary component for a successful technology exchange.

The 8 November 1983 Exchange of Notes provides a new opportunity for significant technology exchange in electro-optic and millimeter-wave technologies as well as other fields. Substantial follow-up by DoD and U.S. industry is necessary if full advantage is to be taken of this new opportunity. Electro-optic and millimeter-wave related areas of interest are given in Figure 7.

Figure 8 shows the dynamics of government-industry interaction. While information exchanges will be established at an inter-government level, much of the actual transfer of technology will occur between U.S. and Japanese industries.

TECHNOLOGIES OF INTEREST

DESIGN/TEST DATA

- T/R MODULES
- LOCAL AREA NETWORKS (LAN)
- * OPTICAL DATA STORAGE
- SEMICONDUCTOR LASERS
- * DFB LASERS AT 1.3 micron
- FIBER OPTIC GYROS
- ACTIVE APERTURE SYSTEMS
- HIGH ELECTRON MOBILITY TRANSISTORS
- * HgCdTe
- SCHOTTKY BARRIER IR DEVICES
- VOICE RECOGNITION & SYNTHESIS
- LITHIUM BATTERIES
- * LASER DIODES
- LAN COMPONENTS

PRODUCTION METHODS & KNOW-HOW

- BROAD-BAND PHASED ARRAYS
- SEEKERS
- * FIBER OPTIC LANs
- FIELD EFFECT TRANSISTORS
- * GaAs WAFERS
- IR FO WAVEGUIDES
- * LIQUID CRYSTAL DISPLAYS
- * ELECTRIC LUMINESCENT DISPLAYS
- LOW COST GYROS
- * III-V MATERIALS
- BARIUM-ZINC-TANTALUM COMPOUND MATERIALS
- AUTOMATED MANUFACTURE OF EO MATERIALS & DEVICES
- ERASABLE OPTICAL DATA STORAGE
- MATERIALS FOR CO_2 LASERS

POTENTIAL SUPPLY SOURCE

- * SOLID STATE IMAGER CHIPS
- PIN/FET
- * LASER DIODES
- APD DETECTORS
- E-O MATERIALS
- * HIGH DENSITY MEMORIES
- MICROWAVE & MMW COMPONENTS
- GaAs WAFERS

* Technologies of High Interest.

FIGURE 7

DYNAMICS OF GOVERNMENT/INDUSTRY INTERACTION

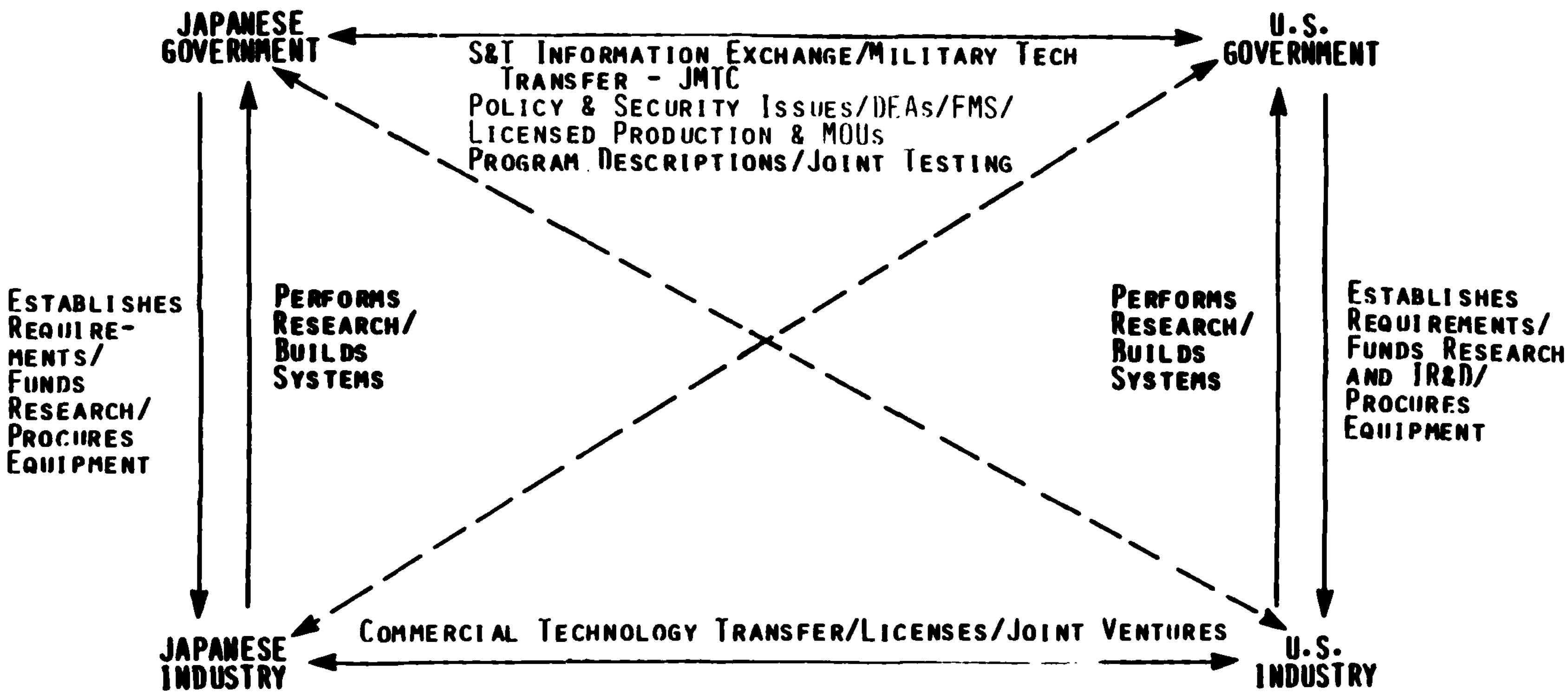


FIGURE 8

APPENDIX A

BIOGRAPHIES

BIOGRAPHIES

JOHN M. MACCALLUM, JR. - Team Leader

Staff Specialist for Surveillance, Communication, and Navigation, Office of the Under Secretary for Research and Engineering

Ph.D. Electrical Engineering; Member Tau Beta Pi, Research Society of America; awarded Air Force Legion of Merit and Naval Research Laboratory Outstanding Performance Award; responsible for technical and budget analysis for Exploratory Development and Advanced Development in all military services in Surveillance, Avionics, and Communications technology; U.S. representative to NATO Defense Research Group on Infrared and Optics and U.S. National Leader for the Technical Cooperation Program (TTCP) (U.S., U.K., Canada, Australia, and New Zealand) on Infrared and Optics.

GEORGE NICHOLAS - Deputy Team Leader

Staff Specialist for Electronic Warfare and Target Acquisition, Office of the Under Secretary of Defense for Research and Engineering

B.S. Electrical Engineering; Charter Member of the Association of Old Crows, Associate Member of the Society of Sigma Xi, Member I.E.E.E. and the Scientific Research Society of America; published several papers in electronic countermeasures; extensive experience in electronic countermeasures research and development

KEN ANDO

Program Manager, Strategic Technology Office, Defense Advanced Research Projects Agency (DARPA)

Ph.D. Solid State Physics; American Physical Society, I.E.E.E., Society of Photo-Optical Instrumentation Engineering, and Sigma Pi Sigma Physics Honorary; two Letters of Commendation and one Professional Recognition Award for work with JPL and NASA. Published several papers on solid state and remote sensing topics; responsible for planning and managing the development of new and innovative concepts in technology areas important to the U.S. Department of Defense's space surveillance needs.

ANTHONY J. DEMARIA

Ph.D. Engineering Physics; holder of 10 honors and awards, 8 professional memberships, 25 patents; published 42 papers and made 53 presentations; has technical and administrative responsibilities for R&D programs in microwave physics, micro-electronics, electro-optic systems research, electromagnetic systems analysis, IR technology, theoretical physics, quantum physics, gas laser physics, and plasma dynamics.

Dr. DeMaria is a consultant to the U.S. Government.

BIOGRAPHIES (Cont'd)

CHARLES FREEMAN

Director of Research, Night Vision and Electro-Optical Laboratory.

M.S. Solid State Engineering; Member Society of Photo-Optical Instrumentation Engineering and Associate Member of the Department of Defense Advisory Group; responsible for planning and directing research programs of NVEOL.

THOMAS S. HARTWICK

Ph.D. Physics; Member American Physical Society and Optical Society of America; experience in non-linear effects in ferrites, CO_2 lasers, far infrared lasers, laser communications, and laser imagery.

Dr. Hartwick is a member of the U.S. Government sponsored Advisory Group on Electron Devices, and consults for the DDR&E Working Group on Lasers.

H. J. KUNO

Ph.D. Electrical Engineering; Member I.E.E.E., American Physical Society, AOC Fellow I.E.E.E.; published more than 100 technical papers on solid state microwave/millimeter-wave oscillators and amplifiers, semiconductor devices, magnetic thin and solid-state plasmas; five patents awarded; engaged in research and development of GaAs devices, microwave and millimeter wave monolithic circuits, and high speed digital ICs.

Dr. Kuno is a consultant to the U.S. Department of Defense.

PATRICK P. MCDERMOTT

Ph.D. Biophysics; awarded NASA's Public Service Medal; papers published on battery performance, degradation and testing; experience in the area of technology transfer and weapon systems analysis.

Dr. McDermott supports components of the U.S. Government policy making structure - OUSDR&E, OSD, DSB, and Congress analyzing scientific and technical development.

BIOGRAPHIES (Cont'd)

SAMUAL MUSA

Ph.D. Applied Physics; I.E.E.E. Fellow; former technical editor of I.E.E.E. Transactions on Geoscience and Remote Sensing.

Dr. Musa is a consultant to the U.S. Department of Defense. He is a former Deputy Director of Military Systems Technology in the Office of the Under Secretary of Defense for Research and Engineering. He directed all DoD S&T programs related to electronic systems.

RONALD F. PAULSON

Chief, Electro-Optics Technology Branch, Air Force Avionics Laboratory.

Ph.D. Physics; M.S. Management; Burka Award; Sloan executive development program selectee; Avionic Lab Manager of the Year; holds several patents in laser and maser excitation concepts.

The Electro-Optics Technology Branch develops low power lasers as well as avionics device development of electro-optic detectors and integrated optical components.

BARRY SPIELMAN

Head, Microwave Technology Branch, Electronics Technology Division, Naval Research Laboratory

Ph.D. Electrical Engineering; Member I.E.E.E. Microwave Theory and Techniques Society, Chairman of 15 national technical committees, member I.E.E.E. Microwave and Millimeter Wave Monolithic Circuits Symposium Steering Committee, Technology Program Committee for I.E.E.E. International Microwave Symposium. Responsible for planning, supervising, conducting, and administering fundamental and applied research in the general areas of microwave and millimeter-wave technologies.

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APPENDIX B

EXCHANGE OF NOTES

EMBASSY OF THE
UNITED STATES OF AMERICA

No. 988

Tokyo, November 8, 1983

Excellency,

I have the honor to acknowledge the receipt of Your Excellency's Note of today's date, which reads as follows:

Tokyo, November 8, 1983

Excellency,

I have the honor to refer to the Mutual Defense Assistance Agreement between Japan and the United States of America signed at Tokyo on March 8, 1954 (hereinafter referred to as "the MDA Agreement"), which provides, *inter alia*, that each Government will make available to the other such equipment, materials, services, or other assistance as the Government furnishing such assistance may authorize, in accordance with such detailed arrangements as may be made between them. The Government of Japan, taking into consideration the assistance extended by the United States of America, including the transfer of defense-related technologies, under the MDA Agreement for the purpose of enhancing the defense capability of Japan, and recognizing the new situation which has been brought about by, *inter alia*, the recent advance of technology in Japan, has decided to reciprocate in the exchange of defense-related technologies in order to ensure the effective operation of the Japan-United States security arrangements, by opening a way for the transfer to the United States of America of military technologies.

In this connection, the Government of Japan confirms that the transfer of any defense-related technologies other than military technologies from Japan to the United States of America has been and is in principle free from restrictions, and welcomes the transfer to the United States of America of defense-related technologies, effected upon the initiative of and by mutual consent of the parties concerned. Such transfer will be encouraged.

His Excellency

Shintaro Abe,

Minister for Foreign Affairs,

Tokyo.

On the basis of the said decision by the Government of Japan, the representatives of the Government of Japan and the Government of the United States of America have held discussions on the ways and means to facilitate the flow of defense-related technologies from Japan to the United States of America and, for such purpose, have decided to establish a framework to implement the transfer of military technologies from Japan to the United States of America. The following is the understanding by the Government of Japan of the results of the above-mentioned discussions:

1. (1) Subject to the detailed arrangements to be concluded under paragraph 3, the Government of Japan will authorize, in accordance with the relevant laws and regulations of Japan, transfer to the Government of the United States of America and the persons authorized by it of such military technologies necessary to enhance defense capability of the United States of America, as will be identified and determined in accordance with the provisions of paragraph 2 below.

(2) For the purposes of the present understanding, the term "military technologies" means such technologies as defined in the Annex attached hereto and includes articles which are necessary to make transfer of military technologies effective and fall under "arms" as defined in the said Annex.

2. (1) A Joint Military Technology Commission (hereinafter referred to as "the JMTC") shall be established as the means for consultation between the Government of Japan and the Government of the United States of America on all matters requiring mutual consultation regarding the implementation of the present understanding. The JMTC may discuss, where appropriate, matters concerning defense-related technologies.

(2) The JMTC shall be composed of two national sections.

The Japanese Section shall be composed of:

a representative of the Defense Agency;

a representative of the Ministry of Foreign Affairs; and

a representative of the Ministry of International Trade and Industry.

The United States Section shall be composed of:

a representative of the Mutual Defense Assistance Office in Japan; and

a representative of the Embassy of the United States of America in Japan.

(3) The JMTC shall serve, in particular, as the means for consultation in identifying military technologies to be transferred.

(4) The JMTC shall meet in Tokyo annually or upon request from either Section.

(5) The relevant information concerning a request of the Government of the United States of America for transfer of military technologies from Japan shall be communicated to the Japanese Section through the diplomatic channel in advance of a JMTC meeting where such request is to be discussed.

(6) Based on the information received from the United States Section and discussion within the JMTC, the Japanese Section shall determine such military technologies as are appropriate to be authorized by the Government of Japan for transfer to the Government of the United States of America and the persons authorized by it and communicate to the United States Section the result thereof through the diplomatic channel.

3. The detailed arrangements providing for, inter alia, military technologies to be transferred, persons who will be party to the transfer, and the detailed terms and conditions of the transfer, will be concluded between the competent authorities of the two Governments in order to implement the present understanding. The competent authorities of the Government of the United States of America will be the Department of Defense; the competent authorities of the Government of Japan will be those to be notified to the Government of the United States of America through the diplomatic channel.

4. The present understanding will be implemented in accordance with the MDA Agreement which provides, inter alia:

(a) that the furnishing and use of any such assistance as may be authorized by either Government shall be consistent with the Charter of the United Nations;

(b) that each Government will make effective use of assistance received pursuant to the MDA Agreement for the purposes of promoting peace and security in a manner that is satisfactory to both Governments, and neither Government, without the prior consent of the other, will devote such assistance to any other purpose; and

(c) that each Government undertakes not to transfer to any person not an officer or agent of such Government, or to any other government, title to or possession of any equipment, materials, or services received pursuant to the MDA Agreement, without the prior consent of the Government which furnished such assistance;

and arrangements concluded thereunder.

5. (1) Pursuant to the provisions of Article III, paragraph 1 of the MDA Agreement, the Government of the United States of America agrees to take such security measures as would guarantee the same degree of security and protection as provided in Japan, and no disclosure to any person not an officer or agent of the Government of the United States of America of classified articles, services or information accepted by the United States of America, will be made without the prior consent of the Government of Japan.

(2) The Government of the United States of America will exempt any taxes or other fiscal levies which may be imposed in the United States of America in connection with the transfer of military technologies authorized by the Government of Japan under the provisions of paragraph 1 above.

I have the honor to propose that, if the above understanding is acceptable to the Government of the United States of America, the present Note and Your Excellency's reply of acceptance shall be regarded as constituting an agreement between the two Governments which shall enter into force on the date of Your Excellency's reply and shall remain in force until six months after the date of the receipt of notice of termination by either Government.

I avail myself of this opportunity to renew to Your Excellency the assurance of my highest consideration.

Shintaro Abe
Minister for Foreign Affairs
of Japan

ANNEX

(1) The term "military technologies" means such technologies as are exclusively concerned with the design, production and use of "arms" as defined in the Policy Guideline of the Government of Japan on Arms Export of February 27, 1976.

(2) (a) The term "arms" as referred to above is defined in the said Policy Guideline as "goods which are listed from Item No. 197 to Item No. 205 of Annexed List 1 of the Export Trade Control Order of Japan, and are to be used by military forces and directly employed in combat". The said Policy Guideline proclaims that equipment related to "arms" production will be treated in the same manner as "arms".

(b) The relevant part of Annexed List 1 of the Export Trade Control Order:

197	Firearms and cartridges to be used therefor (including those to be used for emitting light or smoke), as well as parts and accessories thereof (excluding rifle-scopes)
198	Ammunition (excluding cartridges), and equipment for its dropping or launching, as well as parts and accessories thereof
199	Explosives (excluding ammunition) and jet fuel (limited to that the whole calorific value of which is 13,000 calories or more per gram)
200	Explosive stabilizers
201	Military vehicles and parts thereof
201 - 2	Military vessels and the hulls thereof, as well as parts thereof
201 - 3	Military aircraft, as well as parts and accessories thereof

202	Anti-submarine nets and anti-torpedo nets as well as buoyant electric cable for sweeping magnetic mines
203	Armor plates and military steel helmets, as well as bullet-proof jackets and parts thereof
204	Military searchlights and control equipment thereof
205	Bacterial, chemical, and radio-active agents for military use, as well as equipment for dissemination, protection, detection, or identification thereof

I have the honor to confirm on behalf of the Government of the United States of America that the foregoing understanding is acceptable to the Government of the United States of America and to agree that Your Excellency's Note and this reply shall be regarded as constituting an agreement between the two Governments which shall enter into force on the date of this reply and shall remain in force until six months after the date of the receipt of notice of termination by either Government.

I avail myself of this opportunity to renew to Your Excellency the assurance of my highest consideration.

Michael J. Mansfield

Michael J. Mansfield
Ambassador Extraordinary
and Plenipotentiary of
the United States of America

END

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